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SOVIET OPTICAL RESEARCH IN SUPPORT OF ISOTOPE SEPARATION BY LASERS

[redacted]
OSI/CIA

PREFACE

Separation of isotopes by lasers may eventually provide an inexpensive, efficient uranium separation process. If so, it could have a significant military/political impact by making weapons proliferation possible and a significant economic impact by making more reactor fuel available for sale. [redacted]

SUMMARY AND CONCLUSIONS

Soviet laser isotope separation programs have [redacted] surfaced and are of high quality. The Soviets are actively pursuing development efforts in tunable lasers, laser photochemistry, and high resolution optical spectroscopy which either are or could be applied to the separation of isotopes. None of these programs has been identified with separation of isotopes of military or economic significance, such as uranium, but all could support such an effort. The Soviets appear to be aware of various candidate approaches to separating uranium, as well as problems and efficiencies involved. They have successfully and efficiently separated nitrogen isotopes using lasers with two step molecular photodissociation and also have worked on iodine and rubidium using similar techniques. The lasers required for these efforts are readily available. For most isotopes having military or economic significance, tunable lasers must be developed.

The development of appropriate tunable lasers is the pacing technology for laser isotope separation. Tunable dye lasers are most applicable to production of visible and near infrared wavelengths and tunable spin flip Raman lasers are most applicable at infrared wavelengths. The Soviets have [redacted] scientists engaged in tunable dye laser work [redacted] and have produced dye lasers having greater energy outputs [redacted] However, these large lasers do not represent any advanced technology and, [redacted] the Soviets are somewhat hampered, particularly in the development of continuous wave dye lasers, by a general unavailability of argon lasers for pumping, of good optical coatings, and of dyes of sufficient purity. While the Soviet work currently appears to lag [redacted] in quality, there is no inherent reason why this [redacted] should continue. The Soviet effort on spin flip Raman lasers appears small and [redacted] is hindered by the unavailability of good crystals. This, too, could be quickly overcome with proper allocation of assets.

The Soviets have a [redacted] effort [redacted] in frequency stabilized lasers, another area important in laser isotope separation. While this work has not been identified with tunable (other than CO_2) lasers, it [redacted]

[redacted] requires considerable high resolution optical spectroscopy.

The Soviet effort in laser photochemistry does not appear large, yet the work under way is of high quality and in some cases clearly identified with laser isotope separation. [redacted]

DISCUSSION

Introduction

Laser-induced isotope separation depends upon the fact that atomic and molecular energy levels are different for the various isotopes of an element. These changed energy levels cause a small difference in some absorption spectral lines of the element or molecule. Hence, the spectrally narrow radiation of a laser can be used to excite one isotopic species selectively. Once in the excited state the atom or molecule can undergo a chemical reaction with another species, a reaction it would not undergo or would undergo at a much slower rate if not excited, or be photoionized or photodissociated through illumination with another light source. The separation of the species of interest is then made chemically or electrically.

The three most important optical research areas relating to laser isotope separation are (a) high resolution optical spectroscopy, (b) tunable but frequency stable lasers, and (c) excited state chemistry. High resolution spectra of the atoms or molecules of interest are required in order to choose and examine the appropriate resonance lines. These resonance lines are the principal absorption lines of the material, and the isotope shift, if present, is very small. These spectral lines do not, in general, occur at the wavelengths of available lasers. Hence either some means must be developed to tune available lasers to the required wavelength or a new tunable laser must be developed.

Spin flip Raman lasers and optical parametric oscillators are the most important means of tuning available lasers. In both of these cases, a laser is used to "pump" a crystal; tuning is accomplished by changing a magnetic field around the crystal in the first instance and changing the crystal's temperature in the second. Of the tunable lasers the most important are the dye laser and the carbon dioxide laser. Dyes have broad fluorescent bands ($\sim$10 nanometers) in the visible or near visible portion of the spectrum depending on the dye, and by careful cavity construction they can be tuned continuously over the band. Carbon dioxide lasers can be made to operate on any of several rotational lines in the spectral region of $\sim 10 \pm 0.5$ μm. If such a laser is operated at high pressures, thereby broadening these rotational lines, continuous tunability over this spectral region can be obtained.

Once an atom or molecule is excited by a laser several processes may occur, including radiative deexcitation, collision deexcitation, chemical reaction, photoionization, or photodissociation. Specific knowledge of the rate constants or cross sections of these often competing processes must be obtained in order to design an effective separation process.

The Soviets have efforts, generally of high quality, in all these research areas [redacted]

[redacted]

The Soviets have for several years been interested in X-ray and gamma-ray lasers. One possible active medium for a gamma-ray laser would be one made up entirely of nuclei of a long lived isomeric state. [redacted] Laser isomer separation probably would be more difficult than isotope separation because isomeric shifts in the absorption spectra of atoms or molecules tend to be smaller than isotopic shifts. Morever, this isomer separation would involve relatively heavy nuclei since these long lived isomeric states exist only in the heavy nuclei. [redacted]

Considerable Soviet work is under way in highly frequency-stabilized CO_2 lasers. These lasers are "locked" to specific, very narrow rotational line absorptions in SF_6. This indicates a substantial amount of effort as well as knowledge of the high resolution spectroscopy of hexafluoride molecules. [redacted]

[redacted]

[redacted]

Additional Activities

Additional work in tunable lasers as well as photochemistry is being undertaken [redacted] but its direct applicability to isotope separation is not apparent. [redacted]

[redacted] While LIS is an important application of high power dye lasers, no direct involvement with LIS has been noted [redacted]

[redacted]